OPERATIONAL ISSUES DURING LOW-VISIBILITY TAXI OPERATIONS: A FIELD STUDY

FINAL REPORT

Cooperative Agreement NCC2-486

Western Aerospace Laboratories, Inc
Los Gatos, CA

Anthony D. Andre, Ph.D.
Principal Investigator

Submitted to:
NASA Ames Research Center
Moffett Field, CA
Sandra G. Hart, Technical Monitor

May 6, 1996

OPERATIONAL ISSUES DURING LOW-VISIBILITY TAXI OPERATIONS: A FIELD STUDY

Anthony D. Andre, Ph.D.
Principal Scientist
Western Aerospace Labs, Inc.
NASA Ames Research Center
Moffett Field, CA USA

ABSTRACT

Low-visibility conditions present a host of problems for the National Airspace System. While many modern aircraft are equipped with automation that allows them to land under low-visibility conditions, there is no such corresponding technology to aid the pilots in taxiing the aircraft from runway to gate, or vice versa. Consequently, flight throughput and sequencing is severely constrained, especially at the major airports. Current efforts within NASA, the FAA, and the commercial aviation industry are aimed at developing technologies to increase the efficiency and safety of taxi operations under low-visibility conditions. Based on cockpit observations, pilot interviews, and pilot-controller communications, this paper presents an analysis of current problems experienced by pilots during the taxi operations, and presents their views on key issues related to the introduction of electronic taxi map displays in the cockpit. The data were collected by the author while serving as a flight deck observer aboard thirty-five commercial carrier flights. The implications of these data for the justification and design of advanced cockpit displays for taxi operations are discussed, and the importance of including pilot experiences, opinions, and attitudes in the research and design process is stressed.

INTRODUCTION

Current efforts within NASA, the FAA, and the commercial aviation industry are aimed at developing technologies to increase the efficiency and safety of taxi operations under low-visibility conditions. The goal of these efforts is to provide commercial aircraft with the technology and operating procedures needed for safely achieving the capacity of clear-weather surface operations during instrument-weather conditions. This will be accomplished by reducing delays in taxi operations and runway occupancy times, as well as by providing flight deck integration with surface automation systems and tower guidance.

Before exploring the ways in which advanced technology can aid the pilot (and controllers) to increase the efficiency of low-visibility surface operations, it is important to first understand the problems currently faced by pilots during taxi operations, and the corresponding causes of these problems. Further, it is important to understand the pilot's views and opinions about potential cockpit technology aids, such as electronic taxi map displays, as these preferences and attitudes will have a large influence on the ultimate acceptance and utility of any new technology. To this end, the present paper presents a summary of flight-deck observations, pilot interviews, and pilot-controller communications aimed at determining the main bottlenecks in the current airport surface navigation system, and the issues which must be resolved in order to eliminate these bottlenecks through the introduction of electronic taxi map displays.

DATA COLLECTION METHODS

Participants

The data for this report were collected by the author while serving as a flight deck observer aboard thirty-five commercial carrier flights with the permission of an anonymous airline company and the Federal Aviation Administration. The participants included the thirty-five captains and first officers (and a smaller number of flight engineers) who comprised the flight crews, as well as the FAA ground controllers who communicated with the flight crews observed in the study.

Apparatus

Data were collected aboard the cockpit of a variety of narrow- and wide-body, EFIS- and non-EFIS-equipped commercial jetliners.

Procedure

Interviews. Personal interviews of the flight crew were conducted either during the cruise phase of the flight (above 10,000 ft.), or after parking the aircraft at the gate. These interviews

were often initiated with the general question, "What problems do you currently face when taxiing your aircraft in low-visibility conditions?" The remainder the interview was loosely structured and largely driven by the pilots' previous experiences and observations. At the end of the interview, pilots were shown a conceptual drawing of an electronic taxi map display and were prompted for suggestions as to what features (and procedures) they would want included in such a display. The data were recorded using a pen and notebook.

Observations. Observations of environmental conditions such as visibility, signs, markings and lighting, crew behaviors and actions, and other moving vehicles in the environment were recorded by the author using a pen and notebook and a 35mm camera.

Communications. Communications data were gathered by the author through headphone monitoring of all pilot-pilot and pilot-controller communications. The data were recorded using a pen and notebook.

Data Coding

In the following sections detailing the results of the study, pilot comments from the interviews are always enclosed by quotation marks, flight deck observations by the author are always denoted by italics, pilot-pilot communications are always enclosed by quotation marks in addition to the placement of the letters CPT to refer to the captain and the letters FO to refer to the first officer, and pilot-controller communications are always enclosed by quotation marks in addition to the placement of the letters FC before statements made by the flight crew and the letters GC before statements made by the ground controllers. The names of all participants, airlines, and airline flight numbers have been removed to protect their anonymity.

PLOT INTERVIEWS AND FLIGHT DECK OBSERVATIONS

Current Taxi Problems: Low-Visibility Conditions

As the following quotations attest to, it is no doubt more difficult for pilots to taxi under low-visibility conditions than under high-visibility conditions:

- "Low-visibility taxi situations are the hardest."
- "Taxiing at O'Hare the first time in low-visibility conditions is impossible!"
- "Under low-visibility conditions I taxi at 1/2 to 1/3 the speed of high-visibility conditions."
- "I once had to switch runways while taxiing during 0/0 conditions, but couldn't see anything, so a follow-me truck was sent out to guide me."

- "Delays in taxiing under low visibility conditions are sometimes caused by ground control having to tell you every turn and where you are at a given point in time"
- "Recently at SFO, in dense fog, you couldn't tell where you were, you could only see gate numbers lit up. It took almost one hour from gate to runway."

Clearly, during low-visibility conditions, and at the busier and more complex airports, pilots taxi with more caution, at slower speeds, and sometimes with a less-than-accurate awareness of where they are on the airport surface.

- FC: "I think we are lost"
- GC: "Follow Company 727 and do what he does"

Current Taxi Problems: The Airport Surface Environment

Often, the biggest obstruction to safe and efficient taxi operations is the design of the outside airport surface environment, including surface markings, lighting and signage (Flight Safety Foundation, 1993):

- "SFO is the worst--its like a black hole at night near the ramp areas"
- "Why can't they paint the taxiway numbers on the pavement like they do on the runway?"
- "Gate markings should be bigger and brighter."
- "Some signs are burned out and therefore not visible at night or during poor weather"
- "All airports should be consistent within themselves and between other airports. For example, why not have it such that A, B, and C are always from North to South, numbers go from low to high from North to South, etc. Why is A sometimes next to K?"
- *Pilots note that on their last flight most of the signs were covered with weeds. "Only knew where to go using the map," said the First Officer.*
- *While taxiing at ORD, pilots get confused at several intersections because they don't see signs that indicate which taxiway they are crossing. The problem lies in the fact that the signs are placed a good distance before the intersection (a good feature which provides preview to the pilots) but not repeated at the intersection (a necessary feature which provides confirmation to the pilots). In fact, at a given intersection, the only signs visible are those for the next intersection.*

Current Taxi Problems: Communication

Of course, effective communication is the key to any coordinated activity between two or more agents. Yet, cockpit distractions, inconsistent terminology, misinterpreted clearances, incomplete

clearances, confusing phraseology, and congested radio frequencies combine to make effective communication a challenging goal during taxi operations. Perhaps not surprisingly, poor communication was cited as the causal factor in the second largest number of runway incursions and incidents from 1988 to 1992 (Flight Safety International, 1993):

- FC: "We're lost." GC: "I can't hear anything you are saying."
- GC: "Taxi to gate." CPT: "He didn't say which way to go, did he? Then we'll just go our way."
- GC: "Are you ready for takeoff?" FC: "No, we haven't left the gate yet"
- FC: "Do you still want us to take the inner?" *No answer from Ground Control.*

Current Taxi Problems: Route Changes

One of the most difficult situations faced by pilots is a change of route during the taxi phase:

- "Taxiing to the gate is most difficult when the route is changed in mid-stream. Once you get a mental picture of the route you need to take from the runway to the gate, it's hard to replace it with another route."

This disrupting event occurs fairly often and for a variety of reasons:

- GC: "Can you switch to Runway 1-Right instead?"
- FC: "We need to taxi to test this yaw damper." GC: "Hold on, let me open up the south line for you and put everyone else on the north line."
- GC: "Change to outer at Golf."
  This new clearance was given due to another aircraft stopped on the Inner just after G. We therefore had to get off the Iinner at G (just before the stalled aircraft) and continue on the Outer to our runway.

Current Taxi Problems: Sequence

While much research has been focused on aiding surface navigation (e.g., Zimmerman, 1994), pilots more often know where they need to taxi than when they can taxi:

- GC: "Hold and give way to 2 MD-80's and then you can slip right in."
- GC: "Give way to the 747 up your nose and continue."
- GC: "At T-10 go behind American 767 to 32L."
- "Most of the time the clearance is "follow that guy" at O'Hare and other large airports."

Electronic Taxi Map Displays: Solution or Problem?

Recent technological advancements in sensor, navigation, database and computer graphics technologies have made the introduction of electronic taxi map displays an inevitable addition to

the aircraft cockpit (Zimmerman, 1994). Studies suggest that these displays will increase the efficiency of surface operations, especially under low-visibility conditions (e.g., Batson, Harris & Hunt, 1994; Lasswell and Wickens, 1995). Moreover, as evidenced by the quotes below, many pilots are eager to use electronic taxi map displays:

- "I want a moving map display like they have in a car--one that's track-up."
- "A moving map will help in high-visibility conditions as well as low-visibility conditions in terms of directions and knowing what intersection you are at."
- "The display might help us see signs that are poorly placed or designed in the real world."
- "Most difficult thing is not knowing where you are and what you're coming up to next; that would be tremendous information to have on a map."
- "A moving map will help navigation and incursions more than speed, but that too."
- "Of course I want this! It took me 30 years to learn O'Hare."

Note, however, that not all pilots are equally enthusiastic about electronic taxi map displays:

- "I would rather have IR (infrared) or HUD (head-up dispay) information. IR is better because it is autonomous for each aircraft. I don't want a system that depends on other aircraft, satellites, etc. I want to see a real picture."
- "I would prefer, instead, to have better, brighter and more consistent signage on the taxiways and runways."
- "You must design for lowest common denominator. What if this technology fails on a new pilot, unfamiliar with the airport?"
- "In the end, even with this advanced-technology taxi display, I'm still responsible for the 200 people behind me. So why should I taxi faster, or with any less caution, than I do now?"

The most common concern is the expected increase in heads-down time:

- "I'm not interested in any fancy electronic displays that put my eyes in the cockpit."
- " I don't want a display that keeps me heads-down while taxiing. Even at night and in poor weather I see things out the window (lights on other aircraft, runway markers)."
- "I like idea of moving map display for taxi operations, but it should be a secondary display, not a primary display, since it requires me to be heads-down."
- "If a heads-down display is employed, I prefer that it is a display "option." That is, a display I can refer to at will, but not one that replaces information normally given to me by the outside view and ground control."

Another concern is the failure of the map to detect other aircraft, ramp vehicles and other obstacles:

- "I fear that all moving vehicles (e.g., trucks, luggage carts) would be not be displayed. On the other hand, the display will be too cluttered if it captured all moving vehicles."
- " A moving map wouldn't change my taxi speed much because there's always a chance of objects (trucks, construction, etc.) not showing up on the map."
- "All it takes is one "incident" where some vehicle or object was not picked up by that display and no pilot will use it after that."

Some features pilots would like to see on an electronic taxi map display:

- "I would want my clearance on the map display."
- "An auditory beep when off path or near other aircraft would be useful. Then we would only have to look at display when it beeps, otherwise we are eyes out."
- "At ORD there are only two pads that a 747 can hold in. It would be nice to know where they are on the map."
- "I want to see my wing tip clearance on the map."

TAXI MAP DISPLAY IMPLEMENTATION ISSUES

Future demand for air travel coupled with future airport surface movement technologies will make safer and more efficient low-visibility airport operations a necessary and realistic goal, respectively. However, in order to accomplish this goal, the present data suggests the need for a comprehensive re-design of the current airport surface movement environment, including signs, communication protocols, procedures, and cockpit displays. Collective efforts between NASA, the FAA, and the commercial aviation industry are aimed at improving all of these aspects of the airport surface movement environment. It is argued here that the success of these efforts is predicated on the interaction between researchers and pilots throughout the research and development process.

SUMMARY

Aircraft surface navigation is a complex, dynamic process. This process is most prone to failure during low-visibility conditions and at busy, complex airports. Aircraft taxi operations can be substantially improved through "low-tech" changes to the current signage, surface markings, lighting and communication protocols. The addition of electronic taxi map displays for both pilots and controllers holds the promise of further increased efficiency and safety during low-visibility surface operations. Yet, for these displays to provide invariable assistance to the pilot, a careful,

pilot-centered approach to their design and implementation must be undertaken. Such an approach must appropriately weigh the needs and wants of the pilot community.

ACKNOWLEDGMENTS

The author was supported by Grant #NCC2-486 from the NASA Ames Research Center's Flight Management and Human Factors Division to Western Aerospace Laboratories, Inc. Sandra Hart was the technical monitor. The author thanks the anonymous airline and all of the pilots, flight engineers and ground controllers who contributed to this study. Thanks also to Bill Reynard for administering the cockpit observer pass program. The views expressed in this paper are not necessarily those of NASA or the anonymous airline. Portions of this paper are published in the Proceedings of the International Symposium on Aviation Psychology, Columbus, OH, 1995.

REFERENCES

Batson, V.M., Harris, R. L., and Hunt, P.J. (1994). Navigating the airport surface: Electronic vs. paper maps. 13th Digital Avionics Systems Conference. Phoenix, AZ.

Flight Safety Foundation. (1993). Runway incursions and incidents remain safety issues. Airport Operations, 19 (4), 1-4.

Lasswell, J. W. and Wickens, C.D. (1995). The effects of display location and dimensionality on taxi-way navigation. (Technical Report ARL-95-5/NASA-95-2). University of Illinois Aviation Research Laboratory: Savoy, IL.

Zimmerman, S.L. (1994). Development and test of a pilot display for surface operations. In Proceedings of the SAE AEROTECH '94 Conference. Warrendale, PA: SAE.